

**UTILITY PATENT APPLICATION TRANSMITTAL  
(Small Entity)***(Only for new nonprovisional applications under 37 CFR 1.53(b))*Docket No.  
6006-018Total Pages in this Submission  
43**TO THE ASSISTANT COMMISSIONER FOR PATENTS****Box Patent Application  
Washington, D.C. 20231**

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application invention entitled:

**DEVICE FOR IN VIVO DELIVERY OF BIOACTIVE AGENTS AND METHOD OF MANUFACTURE THEREOF**

and invented by:

**Christopher T. Boyle**If a **CONTINUATION APPLICATION**, check appropriate box and supply the requisite information:☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: \_\_\_\_\_

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Enclosed are:

**Application Elements**

1. ☒ Filing fee as calculated and transmitted as described below
2. ☒ Specification having Sixteen (16) pages and including the following:
  - a. ☒ Descriptive Title of the Invention
  - b. ☐ Cross References to Related Applications *(if applicable)*
  - c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*
  - d. ☐ Reference to Microfiche Appendix *(if applicable)*
  - e. ☒ Background of the Invention
  - f. ☒ Brief Summary of the Invention
  - g. ☒ Brief Description of the Drawings *(if drawings filed)*
  - h. ☒ Detailed Description
  - i. ☒ Claim(s) as Classified Below
  - j. ☒ Abstract of the Disclosure

**UTILITY PATENT APPLICATION TRANSMITTAL**  
**(Small Entity)**

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**43**

**Application Elements (Continued)**

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*  
a. ☐ Formal      b. ☒ Informal      Number of Sheets SIX (6) in Triplicate
4. ☒ Oath or Declaration  
a. ☐ Newly executed *(original or copy)*      ☒ Unexecuted  
b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*  
c. ☒ With Power of Attorney      ☐ Without Power of Attorney  
d. ☐ DELETION OF INVENTOR(S)  
Signed statement attached deleting inventor(s) named in the prior application,  
see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(usable if Box 4b is checked)*  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under  
Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby  
incorporated by reference therein.
6. ☐ Computer Program in Microfiche
7. ☐ Genetic Sequence Submission *(if applicable, all must be included)*  
a. ☐ Paper Copy  
b. ☐ Computer Readable Copy  
c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

**Accompanying Application Parts**

8. ☐ Assignment Papers *(cover sheet & documents)*
9. ☐ 37 CFR 3.73(b) Statement *(when there is an assignee)*
10. ☐ English Translation Document *(if applicable)*
11. ☐ Information Disclosure Statement/PTO-1449      ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Acknowledgment postcard
14. ☒ Certificate of Mailing  
☐ First Class      ☒ Express Mail *(Specify Label No.):* EL 412 126 579 US

# UTILITY PATENT APPLICATION TRANSMITTAL (Small Entity)

(Only for new nonprovisional applications under 37 CFR 1.53(b))

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6006-018

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43

## Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. ☒ Small Entity Statement(s) - Specify Number of Statements Submitted: ONE
17. ☒ Additional Enclosures (please identify below):

Certificate of Express Mailing (1 page)

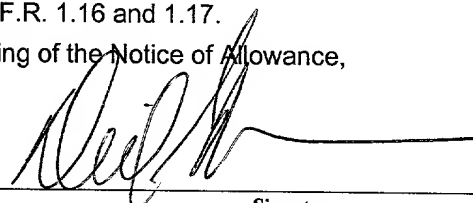
## Fee Calculation and Transmittal

### CLAIMS AS FILED

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	14	- 20 =	0	x \$9.00	\$0.00
Indep. Claims	4	- 3 =	1	x \$40.00	\$40.00
Multiple Dependent Claims (check if applicable) <input type="checkbox"/>					\$0.00
BASIC FEE					\$355.00
OTHER FEE (specify purpose)					\$0.00
TOTAL FILING FEE					\$395.00

- ☒ A check in the amount of **\$395.00** to cover the filing fee is enclosed.
- ☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. **18-2000** as described below. A duplicate copy of this sheet is enclosed.
- ☐ Charge the amount of \_\_\_\_\_ as filing fee.
- ☒ Credit any overpayment.
- ☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.
- ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).

Dated: November 17, 2000



Signature

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Applicant or Patentee: Christopher T. Boyle

Docket No.: 6006-018

Serial or Patent No.:

Filed or Issued: Herewith

For: DEVICE FOR IN VIVO DELIVERY OF BIOACTIVE AGENTS AND METHOD OF MANUFACTURE THEREOF

**VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 C.F.R. § 1.9(F)) - SMALL BUSINESS CONCERN**

I hereby declare that I am

- ☐ the owner of the small business concern identified below;  
☒ an official of the small business concern empowered to act on behalf of the concern identified below.

NAME OF CONCERN Advanced Bio Prosthetic Surfaces, Ltd.

ADDRESS OF CONCERN 4778 Research Drive, San Antonio, Texas 78240

I hereby declare that the above-identified small business concern qualifies as a small business concern defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concern are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed, to and remain with the small business concern identified above with regard to the invention entitled: Device for In Vivo Delivery of Bioactive Agents and Method of Manufacture Thereof by Inventor(s) Christopher T. Boyle.

- ☒ the specification filed herewith  
☐ application Serial No. \_\_\_\_\_, filed \_\_\_\_\_  
☐ Patent No. \_\_\_\_\_, issued \_\_\_\_\_

If the rights held by the above-identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below\* and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e). \*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

FULL NAME \_\_\_\_\_

ADDRESS \_\_\_\_\_

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application for patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful, false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING: Christopher E. Banas

TITLE OF PERSON OTHER THAN OWNER: President

ADDRESS OF PERSON SIGNING: 4778 Research Drive, San Antonio, Texas 78240

SIGNATURE \_\_\_\_\_ Date: \_\_\_\_\_

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICANT: Christopher T. Boyle

SERIAL NO.:

FILING DATE: Herewith

TITLE: DEVICE FOR IN VIVO DELIVERY OF BIOACTIVE AGENTS AND  
METHOD OF MANUFACTURE THEREOF

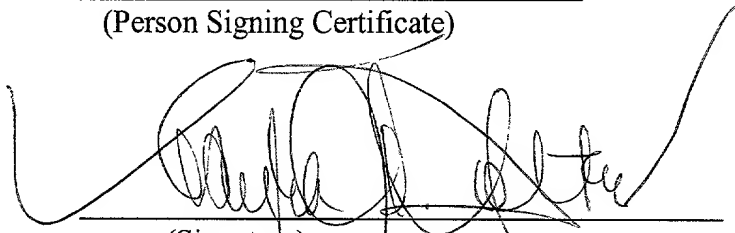
Assist. Commissioner for Patents  
BOX PATENT APPLICATION - FEES  
Washington, D.C. 20231



**CERTIFICATE OF EXPRESS MAIL UNDER 37 CFR 1.10**

I hereby certify that the attached UTILITY PATENT APPLICATION AND ALL ASSOCIATED DOCUMENTS are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" Mailing Label No. EL 412 126 579 US on the date indicated below and is addressed to the Assist. Commissioner for Patents, BOX PATENT APPLICATION - FEES, Washington, D.C. 20231.

Laura A. Molter  
(Person Signing Certificate)

  
(Signature)

11/17/00  
(Date of Signature)

## DEVICE FOR IN VIVO DELIVERY OF BIOACTIVE AGENTS AND METHOD OF MANUFACTURE THEREOF

### Background of the Invention

5           The present invention relates generally to an implantable device for *in vivo* delivery of bioactive compounds. The present invention provides an implantable structural material having a three-dimensional conformation suitable for loading a bioactive agent into the structural material, implanting the structural material *in vivo* and releasing the bioactive agent from the structural agent to deliver a pharmacologically acceptable level of the bioactive agent to an  
10 internal region of a body. More particularly, the present invention relates to an implantable medical device, such as an endoluminal stent, stent-graft, graft, valves, filters, occluders, osteal implant or the like, having cavitated regions with micropores that communicate a bioactive agent from the cavity to an area external the stent.

15           The present invention may be used for any indication where it is desirable to delivery a bioactive agent to a local situs within a body over a period of time. For example, the present invention may be used in treating vascular occlusive disease, disorders or vascular injury, as an implantable contraceptive for delivery of a contraceptive agent delivered intrauterine or subcutaneously, to carry an anti-neoplastic agent or radioactive agent and implanted within or adjacent to a tumor, such as to treat prostate cancer, for time-mediated delivery of  
20 immunosuppressants, antiviral or antibiotic agents for treating of autoimmune disorders such as transplantation rejection or acquired immune disorders such as HIV, or to treat implant or non-implant-related inflammation or infections such as endocarditis.

25           Occlusive diseases, disorders or trauma cause patent body lumens to narrow and restrict the flow or passage of fluid or materials through the body lumen. One example of occlusive disease is arteriosclerosis in which portions of blood vessels become occluded by the gradual build-up of arteriosclerotic plaque, this process is also known as stenosis. When vascular stenosis results in the functional occlusion of a blood vessel the vessel must be returned to its patent condition. Conventional therapies for treatment of occluded body lumens include  
30 dilatation of the body lumen using bioactive agents, such as tissue plasminogen activator (TPA) or vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF) gene transfers which have improved blood flow and collateral development in ischemic limb and myocardium

(S. Yla-Herttuala, *Cardiovascular gene therapy*, Lancet, Jan 15, 2000), surgical intervention to remove the blockage, replacement of the blocked segment with a new segment of endogenous or exogenous graft tissue, or the use of a catheter-mounted device such as a balloon catheter to dilate the body lumen or an arterectomy catheter to remove occlusive material. The dilation of a blood vessel with a balloon catheter is called percutaneous transluminal angioplasty. During angioplasty, a balloon catheter in a deflated state is inserted within an occluded segment of a blood vessel and is inflated and deflated a number of times to expand the vessel. Due to the inflation of the balloon catheter, the plaque formed on the vessel walls cracks and the vessel expands to allow increased blood flow through the vessel.

In approximately sixty percent of angioplasty cases, the blood vessel remains patent. However, the restenosis rate of approximately forty percent is unacceptably high. Endoluminal stents of a wide variety of materials, properties and configurations have been used post-angioplasty in order to prevent restenosis and loss of patency in the vessel.

While the use of endoluminal stents has successfully decreased the rate of restenosis in angioplasty patients, it has been found that a significant restenosis rate continues to exist even with the use of endoluminal stents. It is generally believed that the post-stenting restenosis rate is due, in major part, to a failure of the endothelial layer to regrow over the stent and the incidence of smooth muscle cell-related neointimal growth on the luminal surfaces of the stent. Injury to the endothelium, the natural nonthrombogenic lining of the arterial lumen, is a significant factor contributing to restenosis at the situs of a stent. Endothelial loss exposes thrombogenic arterial wall proteins, which, along with the generally thrombogenic nature of many prosthetic materials, such as stainless steel, titanium, tantalum, Nitinol, etc. customarily used in manufacturing stents, initiates platelet deposition and activation of the coagulation cascade, which results in thrombus formation, ranging from partial covering of the luminal surface of the stent to an occlusive thrombus. Additionally, endothelial loss at the site of the stent has been implicated in the development of neointimal hyperplasia at the stent situs. Accordingly, rapid re-endothelialization of the arterial wall with concomitant endothelialization of the body fluid or blood contacting surfaces of the implanted device is considered critical for maintaining vasculature patency and preventing low-flow thrombosis. To prevent restenosis and thrombosis in the area where angioplasty has been performed, anti-thrombosis agents and other biologically active agents can be employed.

It has been found desirable to deliver bioactive agents to the area where a stent is placed concurrently with stent implantation. Many stents have been designed to delivery bioactive agents to the anatomical region of stent implantation. Some of these stents are biodegradable stents which are impregnated with bioactive agents. Examples of biodegradable impregnated stents are those found in U.S. Pat. Nos. 5,500,013, 5,429,634, and 5,443,458. Other known bioactive agent delivery stents include a stent disclosed in U.S. Pat. No. 5,342,348 in which a bioactive agent is impregnated into filaments which are woven into or laminated onto a stent. U.S. Pat. No. 5,234,456 discloses a hydrophilic stent that may include a bioactive agent adsorbed which can include a biologically active agent disposed within the hydrophilic material of the stent. Other bioactive agent delivery stents disclosed in U.S. Pat. Nos. 5,201,778, 5,282,823, 5,383,927; 5,383,928, 5,423,885, 5,441,515, 5,443,496, 5,449,382, 4,464,450, and European Patent Application No. 0 528 039. Other devices for endoluminal delivery of bioactive agents are disclosed in U.S. Pat. Nos. 3,797,485, 4,203,442, 4,309,776, 4,479,796, 5,002,661, 5,062,829, 5,180,366, 5,295,962, 5,304,121, 5,421,826, and International Application No. WO 94/18906. A directional release bioactive agent stent is disclosed in U.S. Patent No. 6,071,305 in which a stent is formed of a helical member that has a groove in the abluminal surface of the helical member. A bioactive agent is loaded into the groove prior to endoluminal delivery and the bioactive agent is therefore in direct apposition to the tissue that the bioactive agent treats. Finally, International Application No. WO 00/18327 discloses a drug delivery stent in which a tubular conduit is wound into a helical stent. The tubular conduit has either a single continuous lumen or dual continuous lumens that extend the entire length of the conduit. The tubular conduit has regions or segments thereof that has pores to permit drug "seepage" from the conduit. One end of the tubular conduit is in fluid flow communication with a fluid delivery catheter, which introduces a fluid, such as drug into the continuous lumen and through the pores. Where biodegradable or non-biodegradable polymer-based or polymer-coated stents have been used, the polymers cause an immune inflammatory response once the drug is eluted out of the polymer. Where a polymer is employed as the bioactive agent carrier, it is, therefore, desirable to isolate the polymer from body tissues in order to limit the immune inflammatory response after the bioactive agent has eluted as can be accomplished with the present invention.



### **Summary of the Invention**

As used herein the term "bioactive agent" is intended to include one or more pharmacologically active compounds which may be in combination with pharmaceutically acceptable carriers and, optionally, additional ingredients such as antioxidants, stabilizing agents, permeation enhancers, and the like. Examples of bioactive agents which may be used in the present invention include but are not limited to antiviral drugs, antibiotic drugs, steroids, fibronectin, anti-clotting drugs, anti-platelet function drugs, drugs which prevent smooth muscle cell growth on inner surface wall of vessel, heparin, heparin fragments, aspirin, coumadin, tissue plasminogen activator (TPA), urokinase, hirudin, streptokinase, antiproliferatives (methotrexate, cisplatin, fluorouracil, Adriamycin), antioxidants (ascorbic acid, beta carotene, vitamin E), antimetabolites, thromboxane inhibitors, non-steroidal and steroidal anti-inflammatory drugs, immunosuppressants, such as rapamycin, beta and calcium channel blockers, genetic materials including DNA and RNA fragments, complete expression genes, antibodies, lymphokines, growth factors (vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF)), prostaglandins, leukotrienes, laminin, elastin, collagen, nitric oxide (NO) and integrins.

The inventive structural material has a three dimensional conformation having a geometry and construction in which there is an internal cavity or a plurality of internal cavities within the structural material and a conduit or opening or plurality of conduits or openings which communicate between the internal cavity and external the structural material. The three dimensional conformation of the structural material may assume a cylindrical, tubular, planar, spherical, curvilinear or other general shape which is desired and suited for a particular implant application. For example, in accordance with the present invention there is provided an endoluminal stent that is made of a plurality of structural members that define a generally tubular shape for the endoluminal stent. At least some of the plurality of structural members are comprised of the inventive structural material and have at least one internal cavity and at least one conduit or opening which communicates between the internal cavity and external the stent. Alternate types of implantable devices contemplated by the present invention include, without limitation, stent-grafts, grafts, heart valves, venous valves, filters, occlusion devices, catheters, osteal implants, implantable contraceptives, implantable anti-tumor pellets or rods, or other implantable medical devices.

The inventive stent for delivery of bioactive agents consists generally of a plurality of structural elements, at least some of which have internal cavities that retain the bioactive agents, and openings that pass between the internal cavities and the surface of the structural elements to communicate the bioactive agent from the internal cavity external the stent. Other than  
 5 described herein, the present invention does not depend upon the particular geometry, material, material properties or configuration of the stent.

Because of their use as a structural scaffold and the requirement that stents be delivered using transcatheter approaches, stents necessarily are delivered in a reduced diametric state and are expanded or allowed to expand *in vivo* to an enlarged diametric state. Thus, all stents have  
 10 certain structural regions that are subject to higher stress and strain conditions than other structural regions of the stent. Thus, it may be advantageous to position the internal cavities that retain the bioactive agents in structural regions of the stent that are subjected to relatively lower stress and strain during endoluminal delivery and deployment. Alternatively, where delivery of a  
 15 bolus of a bioactive agent is desired, internal cavities may be positioned in regions that undergo large deformation during delivery and deployment thereby forcing the bioactive agent out of the internal cavity under the positive pressure exerted by the deformation. Diffusion forces, then, elute remaining bioactive agent present in either the region of large deformation or the regions of lower stress and strain.

#### **Brief Description of the Drawings**

Figure 1 is a perspective view of an implantable member in accordance with the present invention.

Figure 2 is a perspective view of an endoluminal stent having a plurality of structural member in accordance with the present invention.

Figure 3 is a cross-sectional view taken along line 3-3 of Figure 2.

Figure 4 is a cross-sectional view taken along line 4-4 of Figure 2.

Figure 5 is a fragmentary perspective view of an alternative embodiment of the inventive endoluminal stent in accordance with the present invention.

Figure 6 is a cross-sectional view taken along line 6-6 of Figure 5.

Figure 7 is a cross-sectional view taken along line 7-7 of Figure 5.

Figure 8 is a perspective view of a planar structural element for delivery of a bioactive agent in accordance with the present invention.

Figure 9 is a cross-sectional view taken along line 9-9 of Figure 8.

Figure 10 is a cross-sectional view taken along line 10-10 of Figure 8.

# Detailed Description of the Preferred Embodiments

As noted above, the term "bioactive agent" is intended to encompass one or more pharmacologically active compounds which may be in combination with pharmaceutically acceptable carriers and, optionally, additional ingredients such as antioxidants, stabilizing agents, permeation enhancers, and the like. Examples of bioactive agents which may be used in the present invention include but are not limited to antibiotic drugs, antiviral drugs, neoplastic agents, steroids, fibronectin, anti-clotting drugs, anti-platelet function drugs, drugs which prevent smooth muscle cell growth on inner surface wall of vessel, heparin, heparin fragments, aspirin, coumadin, tissue plasminogen activator (TPA), urokinase, hirudin, streptokinase, antiproliferatives (methotrexate, cisplatin, fluorouracil, Adriamycin), antioxidants (ascorbic acid, beta carotene, vitamin E), antimetabolites, thromboxane inhibitors, non-steroidal and steroidal anti-inflammatory drugs, immunosuppressants, such as rapomycin, beta and calcium channel blockers, genetic materials including DNA and RNA fragments, complete expression genes, antibodies, lymphokines, growth factors (vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF)), prostaglandins, leukotrienes, laminin, elastin, collagen, nitric oxide (NO), and integrins.

With particular reference to Figure 1, the present invention consists generally of a body element 10 having a three-dimensional conformation defining X, Y and Z-axes of the body element 10 and at least one of a plurality of interior cavities 12 defined within the body element 10, and at least one of a plurality of passages or pores 14 which communicate between the at least one of a plurality of interior cavities 12 and exterior to the body element 10. While the body element 10 depicted in Figure 1 is of a generally cylindrical three dimensional conformation, alternative three dimensional conformations, such as planar, spherical, ovular, tetrahedral, curvilinear or virtually any other three dimensional conformation suitable for implantation into a living body is contemplated by the present invention. The plurality of passages 14 have dimensions sufficient to permit the bioactive agent to elute by diffusion,

osmotic pressure or under the influence of a positive pressure applied by cellular in-growth into the plurality of interior cavities 12.

The location of the plurality of passages 14 is dependent upon the particular application for which the body element 10 is intended. For example, with particular reference to Figures 2-5, where the body element 10 is a tubular body 20 made of a plurality of interconnected structural elements 21, such as a stent, stent-graft or graft, which defines a central lumen 22 and has openings 24 at opposing proximal and distal ends of the tubular body 20, the plurality of passages 14 are formed in at least some of the plurality of interconnected structural elements 21 and may be disposed on only the luminal surface 26 or only on the abluminal surface 28 of the tubular body 20, or both. Pores 14 on the luminal surface 26 only will communicate the bioactive agent into the lumen and any body fluid, such as blood, flowing through the central lumen of the tubular body, while pores 14 on only the abluminal surface 26 will communicate the bioactive agent to the abluminal surface of the tubular body. At least a portion of some of the plurality of interior cavities 12 may communicate with either the proximal or distal ends of at least some of the plurality of interconnected structural elements 21. In this case, the proximal and/or distal ends of at least some of the plurality of interconnected structural elements may be tapered such as to self-cannulating into body tissue during delivery and deployment. The bioactive agent retained with the internal cavity 12 which communicates with the proximal and/or distal ends of at least some of the plurality of interconnected structural elements will then pass out of the proximal and/or distal ends in much the same manner as fluid flowing through an injection needle.

In addition to the foregoing positioning of the pores 14, both the plurality of internal cavities 12 and the plurality of pores 14 may be positioned to be discontinuous and in different circumferential or different longitudinal regions of the tubular body 20. Within a single one of the plurality of interconnected structural elements 21, the internal cavities 12 may be separated by a separation member 25, which completely subtends the internal cavity 12, divides it into discrete discontinuous internal cavities 12. The advantage of forming a plurality of discontinuous internal cavities 12 is that it permits loading of different bioactive agents into different regions of the body member 10 or tubular member 20 to isolate different regions for delivery of different bioactive agents to different sites within a body. For example, a first grouping of a plurality of internal cavities 12 and associated plurality of pores 14 may be located at a proximal end of the

tubular body 20, and a second grouping of a plurality of internal cavities 12 and associated plurality of pores 14 may be located at an intermediate region of the tubular body 20, and a third grouping of a plurality of internal cavities 12 and associated plurality of pores 14 may be located at a distal end of the tubular body 20. A first bioactive agent may be loaded into the first and third grouping of a plurality of internal cavities 12, while a second bioactive agent may be loaded into the second grouping of a plurality of internal cavities 12. Where, for example, the tubular body 20 is an endoluminal stent, stent-graft or graft which is implanted post-angioplasty, the proximal and distal ends of the tubular body 20 are anchored adjacent to healthy tissue while the intermediate region of the tubular body 20 are positioned adjacent to the diseased or injured tissue. In this configuration, a first bioactive agent, such as an endothelial growth factor and/or contrast medium to impart enhanced radioopacity to the tubular body 20 may be carried in the first and third groups of a plurality of internal cavities 12 and associated pores 14, while an anticoagulant, such as heparin, may be carried in the second group of a plurality of internal cavities 12 and associated pores 14. In this manner, the tubular body has enhanced radioopacity to aid in delivery and deployment and endothelial growth factors to enhance endothelialization of the tubular body 20, while delivering an anticoagulant directly to the site of the tissue lesion.

Moreover, where the internal cavities 12 are discontinuous, the plurality of pores 14 may be configured to include degradable plugs which degrade at different rates to expose different bioactive agents in the internal cavities 12 to the body at different points in time. Alternatively or additionally, the degradable plugs may degrade at different to expose the same bioactive agent in different internal cavities 12 at different periods of time to effectively elongate the period of time during which the bioactive agent is delivered.

The body element 10 is preferably formed of a metal such as titanium, vanadium, aluminum, nickel, tantalum, zirconium, chromium, silver, gold, silicon, magnesium, niobium, scandium, platinum, cobalt, palladium, manganese, molybdenum and alloys thereof, such as zirconium-titanium-tantalum alloys, nitinol, or stainless steel.

Turning to Figures 5-7 there is illustrated an alternative embodiment of the inventive endoluminal stent fabricated from a plurality of tubular structural elements 31 formed into a tubular stent and having a desired geometry. It will be appreciated that the generally hexagonal cell geometric pattern illustrated in Figure 5 is merely exemplary and a myriad of different geometries of different geometric complexities are contemplated by the invention. Each of the

tubular structural elements 31 has a central lumen 37 that forms the internal cavity within each structural element 31. A plurality of separation member 38 may be provided to subdivide the internal cavity 37 into a plurality of discontinuous internal cavities 37. Each of the tubular structural elements 31 has a plurality of openings 36 which communicate between the internal cavity 37 and one or both of a luminal surface 33 or an abluminal surface 35 of each of the plurality of tubular structural elements 31. The tubular structural elements 31 may assume any transverse cross-sectional configuration having a central lumen.

Those of ordinary skill in the stent forming arts will understand that in order to form a tubular endoluminal stent of tubular elements 31, it is necessary to join at least some of the plurality of tubular elements 31. Conventionally, a plurality of spot-welds 34 which serve to interconnect sections of individual tubular elements 31 in juxtaposed relationship to one and other. The plurality of spot welds 34 may also be employed to seal the internal cavity 37 at the position of the spot weld, thereby creating a separation member 38 within the internal cavity 37 of each individual tubular element 31 and forming a discontinuous internal cavity 37.

As noted above, the plurality of openings 36 are dimensioned to permit the bioactive agent to elute from the at least one of a plurality of internal cavities 37 and through the associated plurality of openings 36 by diffusion, osmotic pressure or under the influence of a positive pressure applied by cellular in-growth into the plurality of internal cavities 37 or under positive pressure applied by stress and/or strain exerted on the plurality of internal cavities 37 due to deformation of the individual tubular structural elements 31. Additionally, the positioning of the plurality of openings 36 relative to the individual tubular structural elements 31 and to the endoluminal stent as a whole may be adapted to deliver varying quantities of or different bioactive agents from different regions of the tubular structural elements 31 or different regions of the endoluminal stent 30. Moreover, proximal and/or distal ends of individual tubular structural elements 31 may be tapered so as to form self-cannulating ends of the individual tubular structural elements 31 which penetrate body tissue and permit the bioactive agent to be communicated from the internal cavity 37 out the proximal or distal end of the tubular structural element 31 in a manner similar to a hypodermic needle.

In accordance with another embodiment of the present invention, and as illustrated in Figures 8-10, there is provided an implantable device 40 which consists of a structural body 42 having a three-dimensional conformation extending in the X-axis, Y-axis and Z-axis

dimensionally. While the illustrated embodiment of the structural body 42 is planar, those of ordinary skill in the medical device fabrication art will understand that it is within the skill of the artisan to fabricate the structural body 42 of any desired three-dimensional conformation depending upon the desired use and indication of the implantable device 40. The three-  
5 dimensional conformation of the structural body 42 may be cylindrical, tubular, quadrilinear, planar, spherical, ovular, tetrahedral, curvilinear or virtually any other three-dimensional conformation suitable for implantation into a living body.

Like the above-described embodiments, the structural body 42 has at least one of a plurality of internal cavities 47, each of which carry a bioactive agent 47, and a plurality of  
10 openings 44 which pass from at least one upper 46, lower 48 or lateral 45 surface of the structural body 42, through the Z-axis thickness of the body and communicate with the at least one of a plurality of internal cavities 47 in the structural body 42. Where a plurality of internal cavities 47 are provided within the structural body 42, a plurality of bioactive agents 49 may be loaded into the structural body 42 with one or more bioactive agents 49 being loaded into each of  
15 the plurality of internal cavities 47.

Each of the above-described preferred embodiments of the present invention may be fabricated by a number of methods. In accordance with present invention, it is contemplated that either forming wrought metal parts, such as capillary tubing, into the implantable device or forming the implantable devices by vacuum deposition techniques are the preferred method of  
20 making the implantable structural elements of the present invention. Where an implantable device is to be fabricated of a plurality of individual tubular elements, such as depicted in Figures 5-7, pre-existing microtubular members having an outer diameter, for example, between 60 and 400µm and a wall thickness of between 10 and 350µm, may be employed to fabricate extremely small dimensioned devices suitable for intracranial or coronary artery applications.

25 The microtubular members may be formed into a cylindrical endoluminal device, such as by braiding or bending and joining microtubular members together by spot welding. Where ends of the microtubular members are formed to be self-cannulating, the self-cannulating ends may be exposed on the abluminal surface of an endoluminal device at any point along the longitudinal axis thereof. The plurality of openings passing through the wall of each of the individual tubular  
30 elements may be formed by microdrilling the openings through the wall and into the internal cavity or lumen of the individual tubular members. The plurality of openings may be laser cut,

etched or formed by EDM methods, and may be formed either pre- or post- formation of the tubular elements into the three-dimensional conformation of the implantable device. Where an implantable device is to be formed from non-preexisting structural elements, vacuum deposition techniques may be employed to form the implantable structural body, such as sputtering, reactive ion etching, chemical vapor deposition, plasma vapor deposition, or the like, as are known in the microelectronics fabrication arts and are more fully described in co-pending, commonly assigned U.S. Patent Application Serial No. 09/443,929, filed November 19, 1999, which is hereby incorporated by reference. Because, the internal cavities and openings must be formed during deposition, the vacuum deposition techniques must be modified to deposit requisite patterns of sacrificial material to form the regions of the internal cavities and openings, over a base layer of structural material, then depositing a second layer of structural material over the sacrificial material and the base layer. The sacrificial material may then be removed, such as by etching, to leave the internal cavities and plurality of openings formed within the deposited bulk material.

Regardless of which fabrication method is employed, the bioactive agent must be loaded into the internal cavities of the implantable device. Loading of the bioactive agent may be accomplished by flowing a liquid or semi-liquid state of the bioactive agent through the plurality of openings and into the internal cavities, either throughout the entire device or in regions of the implantable device. Flow loading may be facilitated by applying positive pressure, temperature change or both, such as is used in hot isostatic pressing (HIP). In HIP the pressurizing medium is typically a gas, and the process is carried out at elevated temperatures for specific time periods. While HIP is typically utilized to densify materials, to heal casting defects and voids, or to bond similar or dissimilar materials it may be used to drive a fluid or semi-fluid from external the implantable device into the internal cavities of the implantable device. Alternative, diffusion-mediated loading, osmotic loading or vacuum loading may be employed to load the bioactive agent into the internal cavities.

While the present invention has been described with reference to its preferred embodiments, those of ordinary skill in the art will understand and appreciate that variations in structural materials, bioactive agents, fabrication methods, device configuration or device indication and use may be made without departing from the invention, which is limited in scope only by the claims appended hereto.



What is claimed is:

1. An implantable body, comprising:

a structural body having a three-dimensional conformation and a thickness thereto, at least  
 5 one internal cavity residing within the thickness of the structural body, and at least one of a  
 plurality of openings communicating between the at least one internal cavity and external to the  
 structural body, and at least one bioactive agent disposed in the at least one internal cavity, the at  
 least one bioactive agent capable of being released from within the at least one internal cavity  
 through the at least one of a plurality of openings, upon implantation of the structural body into a  
 10 body in need thereof.

2. The implantable body according to Claim 1, wherein the structural body further  
 comprises an endoluminal stent being composed of a plurality of interconnected individual  
 structural elements, each of the plurality of interconnected individual structural elements having  
 15 the at least one internal cavity, the at least one of a plurality of openings and the at least one  
 bioactive agent therein.

3. The implantable body according to Claim 1, wherein the structural body further  
 comprises a material selected from the group consisting of titanium, vanadium, aluminum,  
 20 nickel, tantalum, zirconium, chromium, silver, gold, silicon, magnesium, niobium, scandium,  
 platinum, cobalt, palladium, manganese, molybdenum and alloys thereof, such as zirconium-  
 titanium-tantalum alloys, nitinol, and stainless steel.

4. The implantable body according to Claim 1, wherein the bioactive agent further  
 25 comprises a pharmacologically active agent selected from the group of antibiotic drugs, antiviral  
 drugs, neoplastic agents, steroids, fibronectin, anti-clotting drugs, anti-platelet function drugs,  
 drugs which prevent smooth muscle cell growth on inner surface wall of vessel, heparin, heparin  
 fragments, aspirin, coumadin, tissue plasminogen activator (TPA), urokinase, hirudin,  
 streptokinase, antiproliferatives (methotrexate, cisplatin, fluorouracil, Adriamycin), antioxidants  
 30 (ascorbic acid, beta carotene, vitamin E), antimetabolites, thromboxane inhibitors, non-steroidal  
 and steroidal anti-inflammatory drugs, immunosuppressants, such as rapomycin, beta and calcium

channel blockers, genetic materials including DNA and RNA fragments, complete expression genes, antibodies, lymphokines, growth factors (vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF)), prostaglandins, leukotrienes, laminin, elastin, collagen, nitric oxide (NO), and integrins.

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5. An endoluminal stent, comprising:

a tubular member having a central lumen passing longitudinally through the tubular member and open at opposing ends of the tubular member, a luminal surface and an abluminal surface and a wall thickness defined therebetween, at least one internal cavity residing within the wall thickness in at least some portions of the tubular member, a plurality of openings communicating between the at least one internal cavity and at least one of the luminal surface, abluminal surface, proximal end or distal end of the tubular member, and at least one bioactive agent disposed in the at least one internal cavity.

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6. The implantable body according to Claim 5, wherein the structural body further comprises a material selected from the group consisting of titanium, vanadium, aluminum, nickel, tantalum, zirconium, chromium, silver, gold, silicon, magnesium, niobium, scandium, platinum, cobalt, palladium, manganese, molybdenum and alloys thereof, such as zirconium-titanium-tantalum alloys, nitinol, and stainless steel.

15

7. The implantable body according to Claim 6, wherein the bioactive agent further comprises a pharmacologically active agent selected from the group of antibiotic drugs, antiviral drugs, neoplastic agents, steroids, fibronectin, anti-clotting drugs, anti-platelet function drugs, drugs which prevent smooth muscle cell growth on inner surface wall of vessel, heparin, heparin fragments, aspirin, coumadin, tissue plasminogen activator (TPA), urokinase, hirudin, streptokinase, antiproliferatives (methotrexate, cisplatin, fluorouracil, Adriamycin), antioxidants (ascorbic acid, beta carotene, vitamin E), antimetabolites, thromboxane inhibitors, non-steroidal and steroidal anti-inflammatory drugs, immunosuppressants, such as rapamycin, beta and calcium channel blockers, genetic materials including DNA and RNA fragments, complete expression genes, antibodies, lymphokines, growth factors (vascular endothelial growth factor (VEGF) and

25

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fibroblast growth factor (FGF)), prostaglandins, leukotrienes, laminin, elastin, collagen, nitric oxide (NO), and integrins.

8. An endoluminal stent, comprising:

a cylindrical member comprised of a plurality of structural elements defining walls of the cylindrical member, a plurality of discontinuous interior cavities disposed in at least some of the plurality of structural elements, and a plurality of openings communicating between each of the plurality of discontinuous interior cavities and external the stent, and at least one bioactive agent disposed within the plurality of discontinuous interior cavities.

9. The implantable body according to Claim 8, wherein the structural body further comprises a material selected from the group consisting of titanium, vanadium, aluminum, nickel, tantalum, zirconium, chromium, silver, gold, silicon, magnesium, niobium, scandium, platinum, cobalt, palladium, manganese, molybdenum and alloys thereof, such as zirconium-titanium-tantalum alloys, nitinol, and stainless steel.

10. The implantable body according to Claim 9, wherein the bioactive agent further comprises a pharmacologically active agent selected from the group of antibiotic drugs, antiviral drugs, neoplastic agents, steroids, fibronectin, anti-clotting drugs, anti-platelet function drugs, drugs which prevent smooth muscle cell growth on inner surface wall of vessel, heparin, heparin fragments, aspirin, coumadin, tissue plasminogen activator (TPA), urokinase, hirudin, streptokinase, antiproliferatives (methotrexate, cisplatin, fluorouracil, Adriamycin), antioxidants (ascorbic acid, beta carotene, vitamin E), antimetabolites, thromboxane inhibitors, non-steroidal and steroidal anti-inflammatory drugs, immunosuppressants, such as rapamycin, beta and calcium channel blockers, genetic materials including DNA and RNA fragments, complete expression genes, antibodies, lymphokines, growth factors (vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF)), prostaglandins, leukotrienes, laminin, elastin, collagen, nitric oxide (NO), and integrins.

11. An endoluminal stent for delivering a bioactive agent to a situs in a body, comprising a plurality of structural elements interconnected to form a cylindrical member, each of the plurality of structural elements a the wall thickness further comprising a plurality of lamina positioned concentrically through the wall thickness and a plurality of tubular member having an exterior surface and an interior surface together defining a tubular member thickness of said tubular member, said tubular member having a recessed active agent receiving portion formed in said exterior surface, said recessed active agent receiving portion having a depth less than said tubular member thickness, said recessed active agent receiving portion containing at least one active agent.

12. The endoluminal stent according to Claim 11, wherein the endoluminal stent is fabricated by vapor deposition of at least one metal.

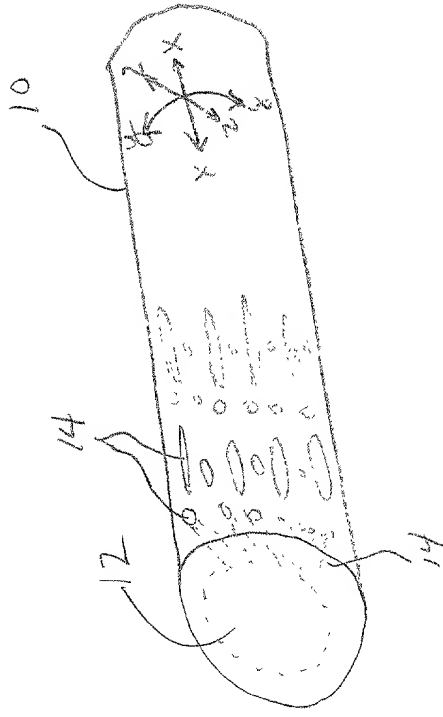
13. The implantable body according to Claim 12, wherein the at least one metal is selected the group consisting of titanium, vanadium, aluminum, nickel, tantalum, zirconium, chromium, silver, gold, silicon, magnesium, niobium, scandium, platinum, cobalt, palladium, manganese, molybdenum and alloys thereof, such as zirconium-titanium-tantalum alloys, nitinol, and stainless steel.

14. The implantable body according to Claim 11, wherein the bioactive agent further comprises a pharmacologically active agent selected from the group of antibiotic drugs, antiviral drugs, neoplastic agents, steroids, fibronectin, anti-clotting drugs, anti-platelet function drugs, drugs which prevent smooth muscle cell growth on inner surface wall of vessel, heparin, heparin fragments, aspirin, coumadin, tissue plasminogen activator (TPA), urokinase, hirudin, streptokinase, antiproliferatives (methotrexate, cisplatin, fluorouracil, Adriamycin), antioxidants (ascorbic acid, beta carotene, vitamin E), antimetabolites, thromboxane inhibitors, non-steroidal and steroidal anti-inflammatory drugs, immunosuppressants, such as rapomycin, beta and calcium channel blockers, genetic materials including DNA and RNA fragments, complete expression genes, antibodies, lymphokines, growth factors (vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF)), prostaglandins, leukotrienes, laminin, elastin, collagen, nitric oxide (NO), and integrins.

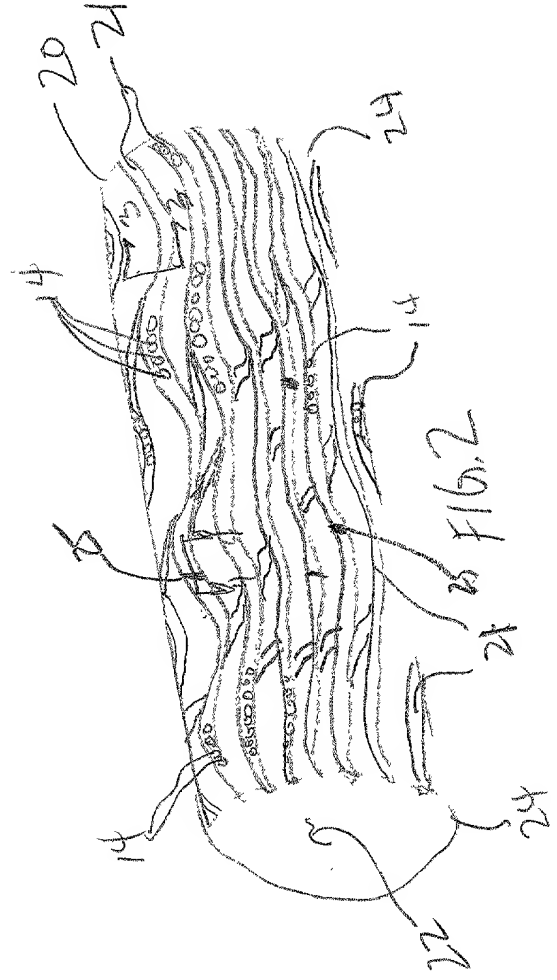
**Abstract**

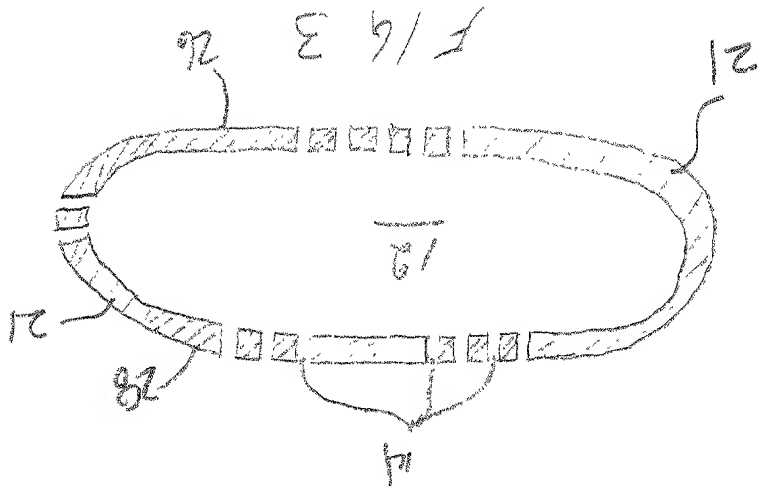
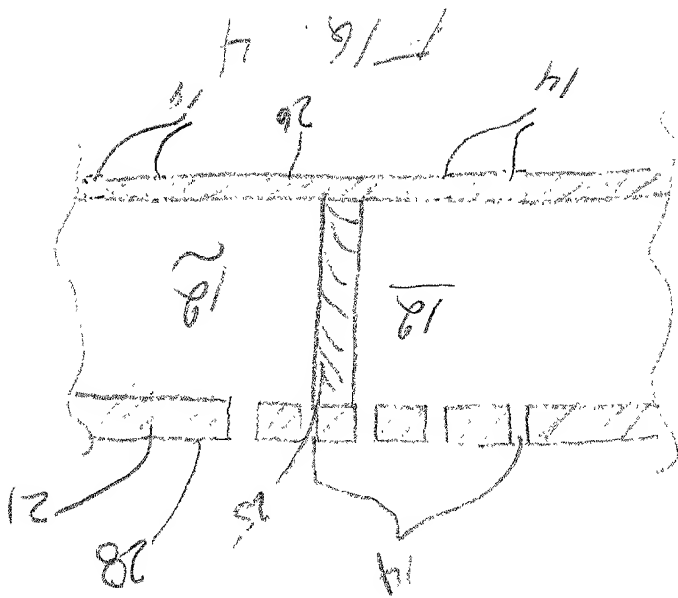
The present invention consists of an implantable structural element for *in vivo* delivery of bioactive active agents to a situs in a body. The implantable structural element may be configured as an implantable prosthesis, such as an endoluminal stent, cardiac valve, osteal  
5 implant or the like, which serves a dual function of being prosthetic and a carrier for a bioactive agent. Alternatively, the implantable structural element may simply be an implantable article that serves the single function of acting as a time-release carrier for the bioactive agent.

Parameter	Value	Parameter	Value
Mean	1.0	Mean	1.0
Standard deviation	0.5	Standard deviation	0.5
Minimum	0.0	Minimum	0.0
Maximum	2.0	Maximum	2.0
Mode	1.0	Mode	1.0
Median	1.0	Median	1.0
Range	2.0	Range	2.0
Interquartile range	1.0	Interquartile range	1.0
Skewness	0.0	Skewness	0.0
Kurtosis	0.0	Kurtosis	0.0
Correlation coefficient	0.0	Correlation coefficient	0.0
Chi-square	0.0	Chi-square	0.0
F	0.0	F	0.0
T	0.0	T	0.0
U	0.0	U	0.0
W	0.0	W	0.0
Z	0.0	Z	0.0
Y	0.0	Y	0.0
X	0.0	X	0.0
V	0.0	V	0.0
U	0.0	U	0.0
T	0.0	T	0.0
S	0.0	S	0.0
R	0.0	R	0.0
Q	0.0	Q	0.0
P	0.0	P	0.0
O	0.0	O	0.0
N	0.0	N	0.0
M	0.0	M	0.0
L	0.0	L	0.0
K	0.0	K	0.0
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I	0.0	I	0.0
H	0.0	H	0.0
G	0.0	G	0.0
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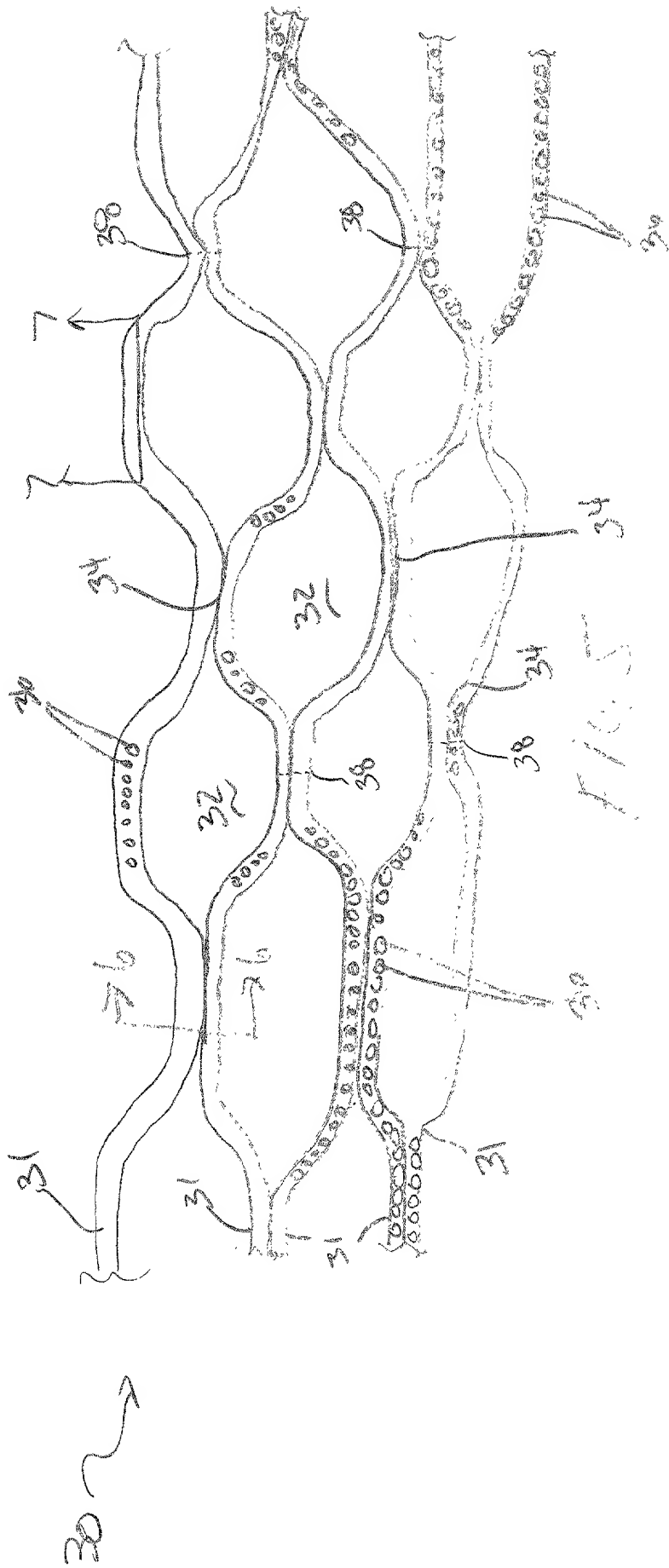


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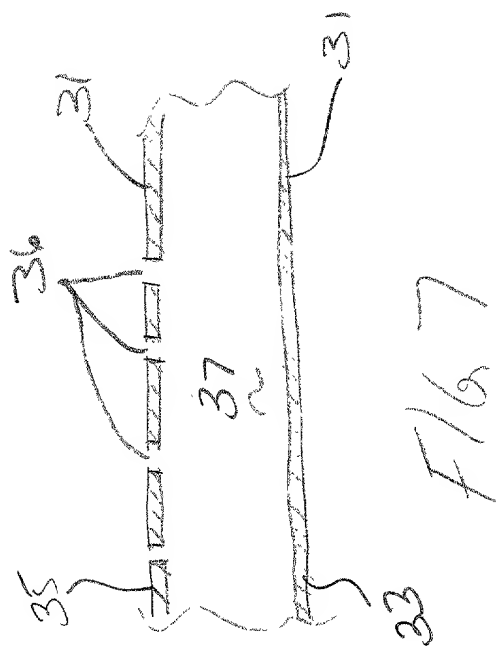
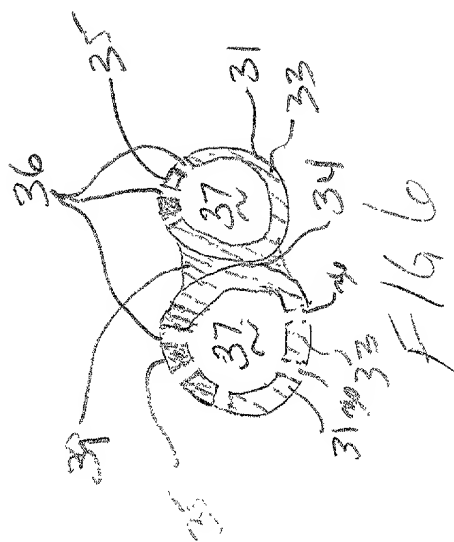




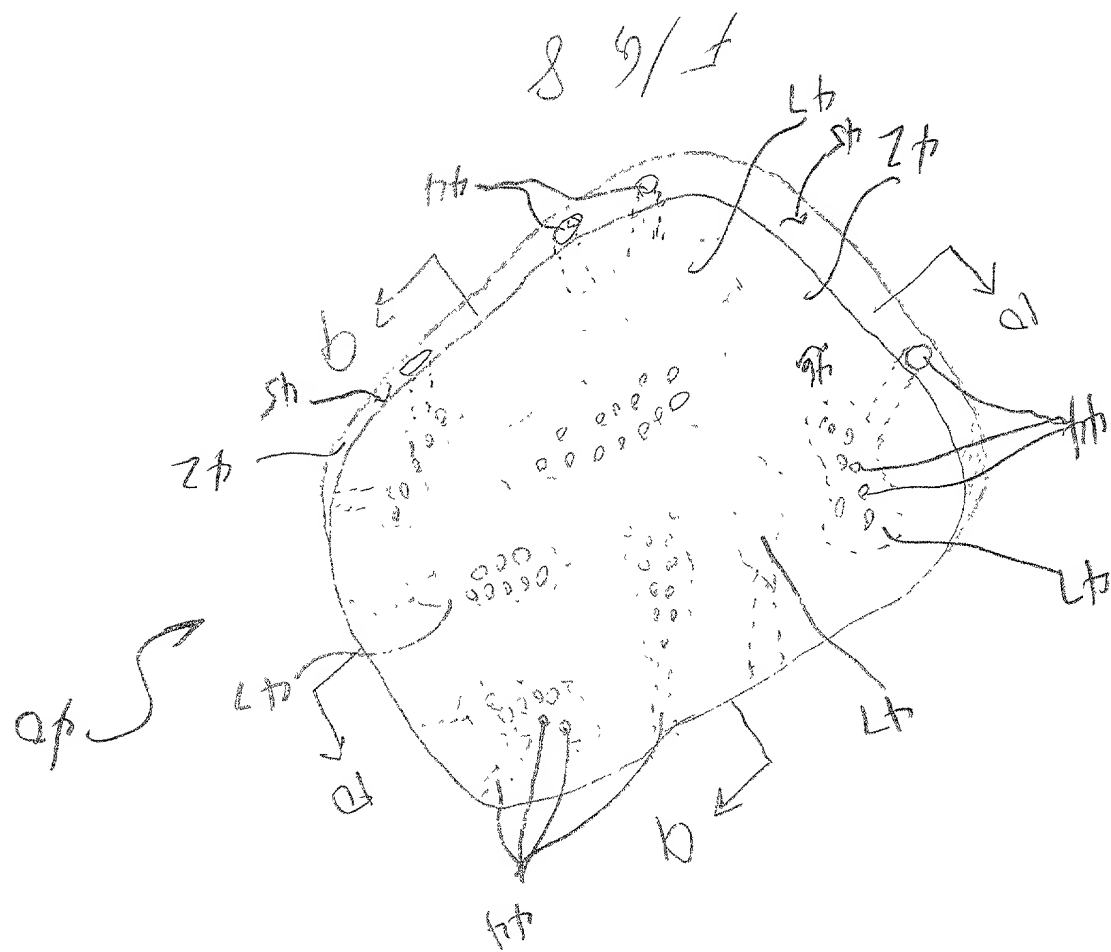
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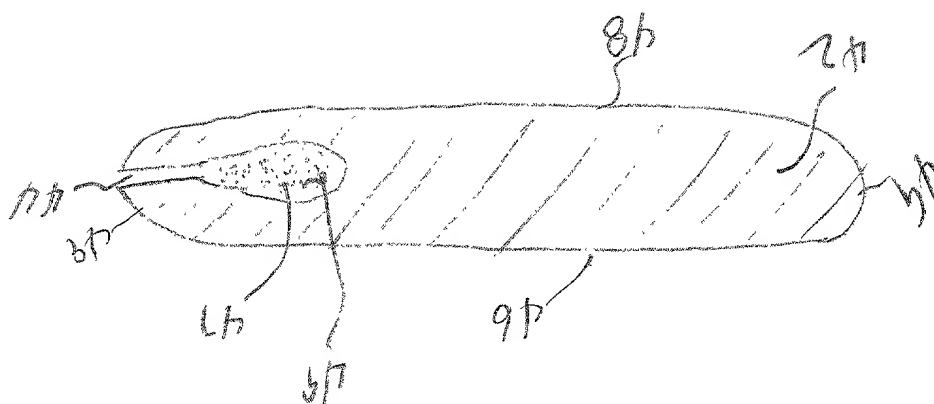


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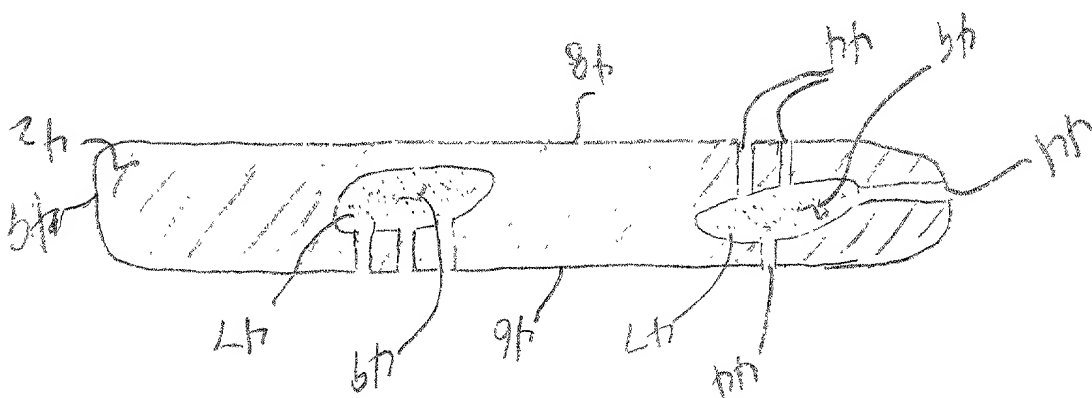


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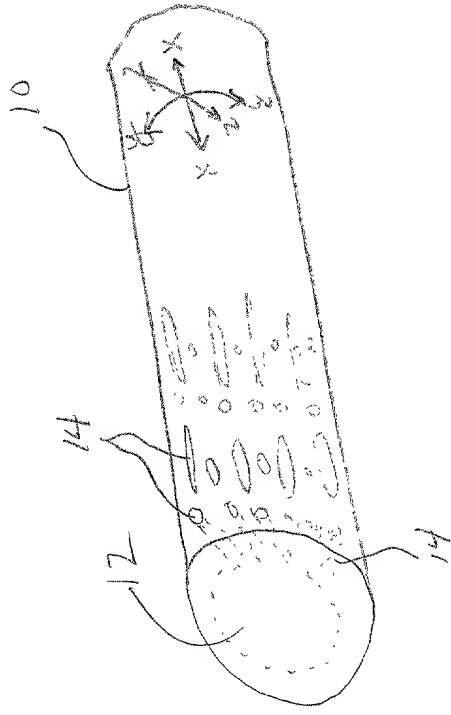
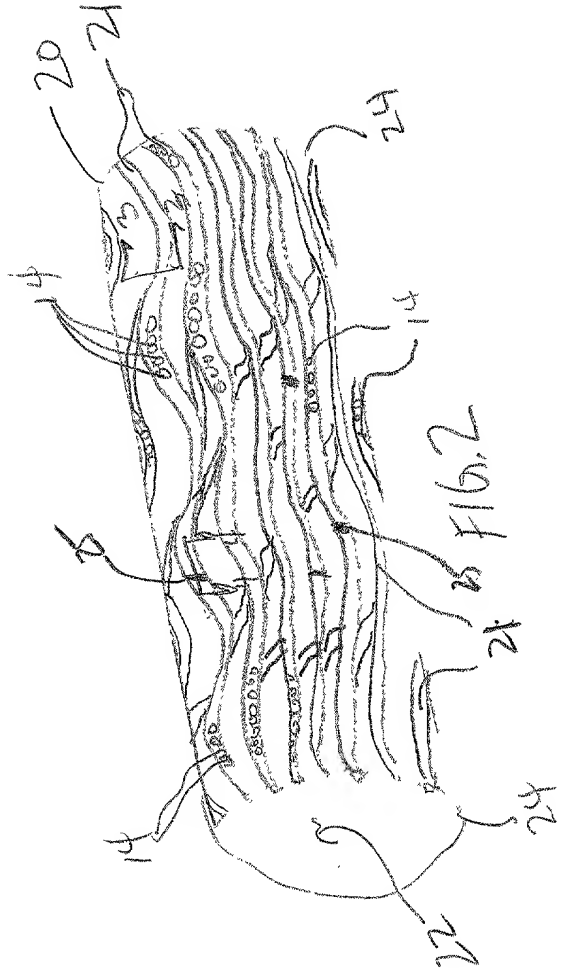
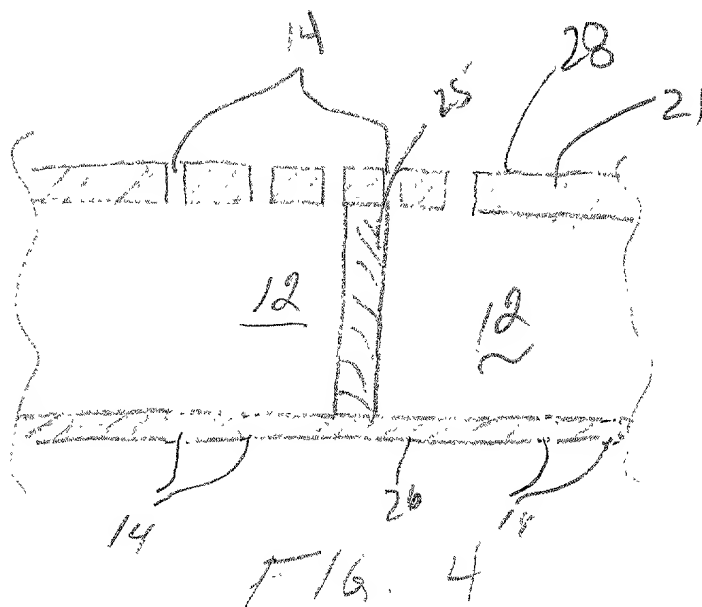
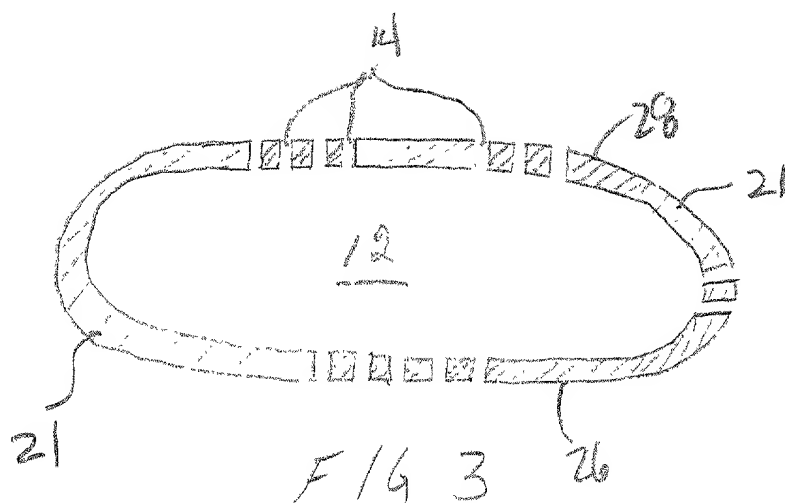
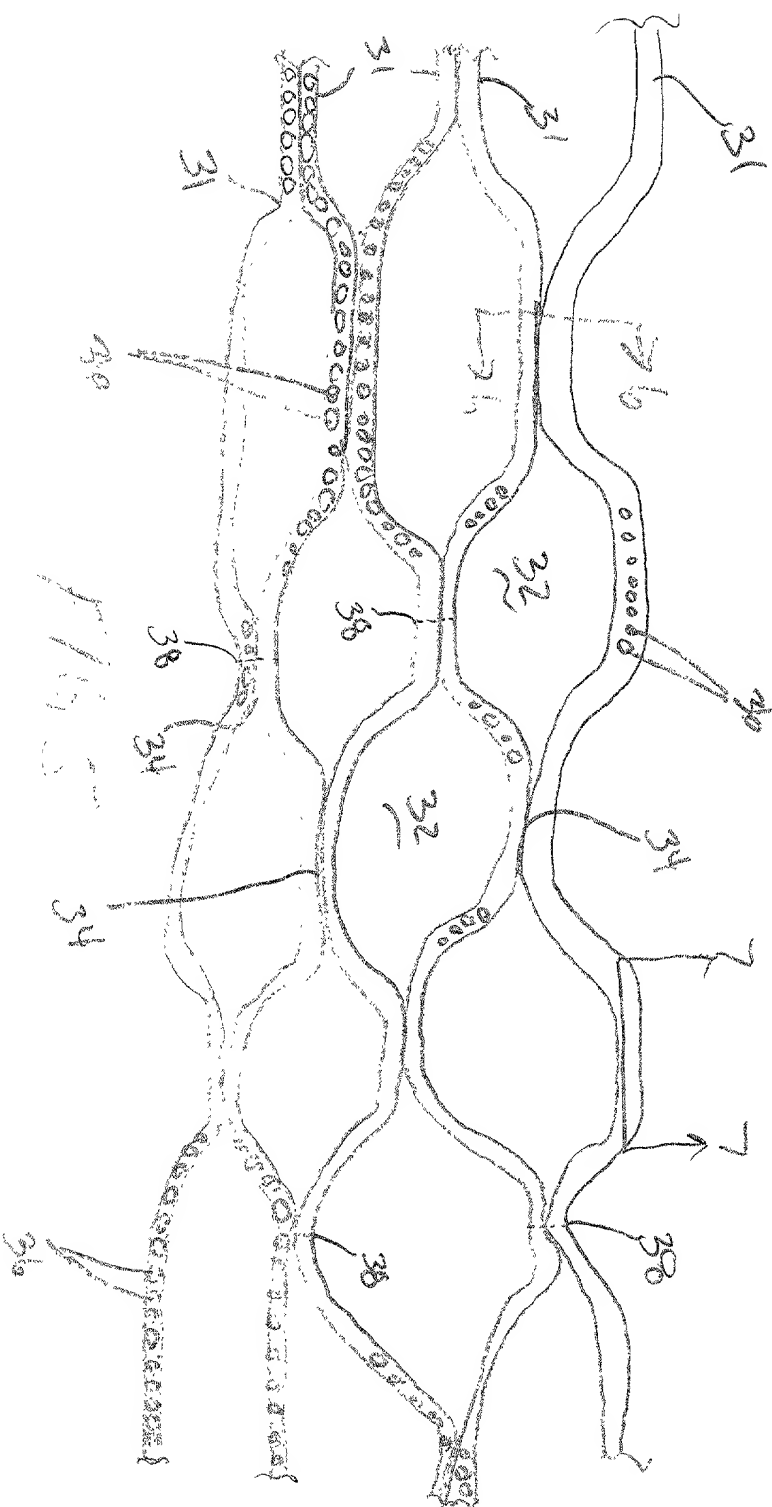


Fig. 1



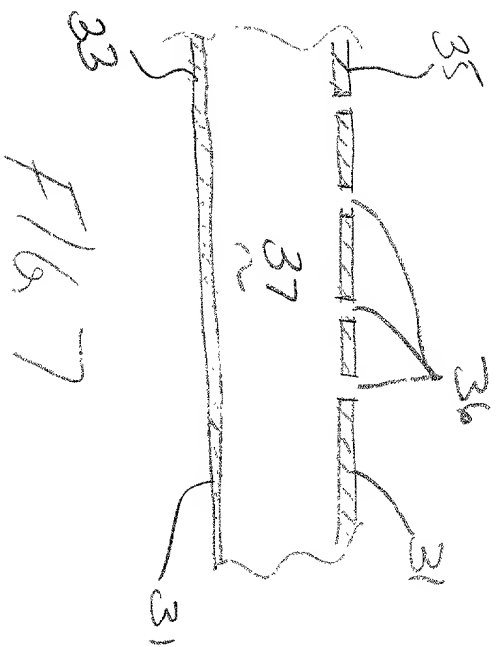
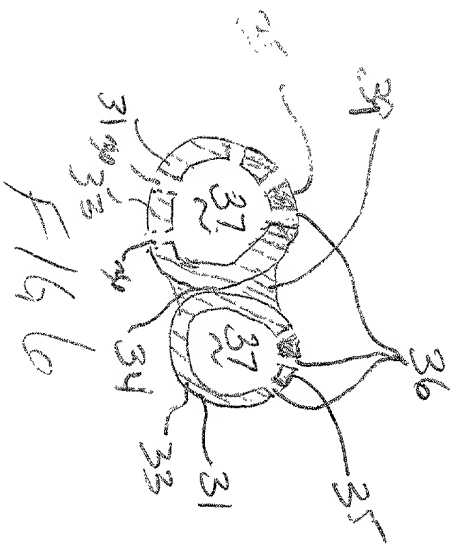


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A hand-drawn diagram of a circular structure, possibly a cross-section of a dome or a similar architectural element. The diagram includes several labels and arrows:

- 44**: Located at the top center, pointing to a small structure on the roof.
- 47**: Multiple instances, pointing to various parts of the structure, including the roof and the main body.
- 40**: A large arrow pointing from the right side towards the center.
- 42**: Located on the right side, pointing to a specific part of the structure.
- 45**: Located on the right side, pointing to a specific part of the structure.
- 9**: Located on the right side, pointing to a specific part of the structure.
- 44**: Located at the bottom right, pointing to a small structure on the roof.
- 42**: Located at the bottom left, pointing to a specific part of the structure.
- 45**: Located at the bottom left, pointing to a specific part of the structure.
- 47**: Located at the bottom left, pointing to a specific part of the structure.
- 10**: Located on the left side, pointing to a specific part of the structure.
- 44**: Located on the left side, pointing to a specific part of the structure.
- 47**: Located on the left side, pointing to a specific part of the structure.

The diagram also includes several arrows indicating direction or flow, and a large arrow labeled **40** pointing from the right side towards the center. The overall structure is circular with a central area containing some internal details.

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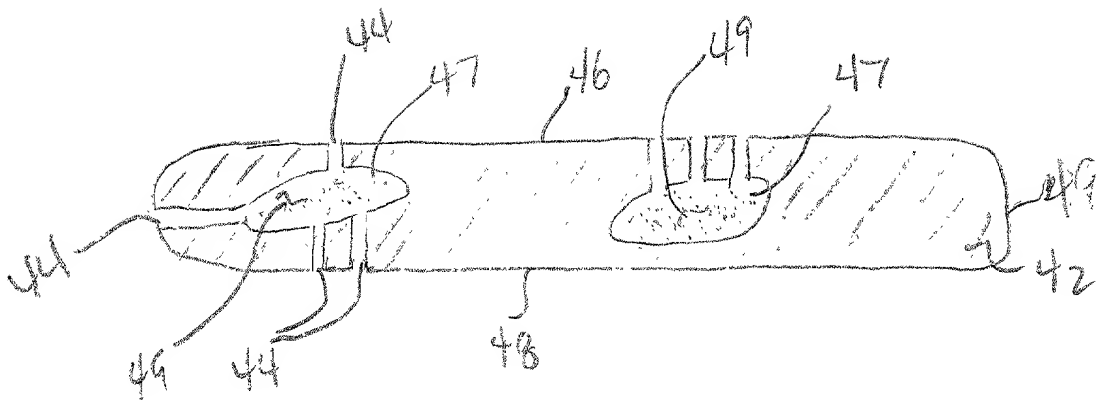


FIG. 9

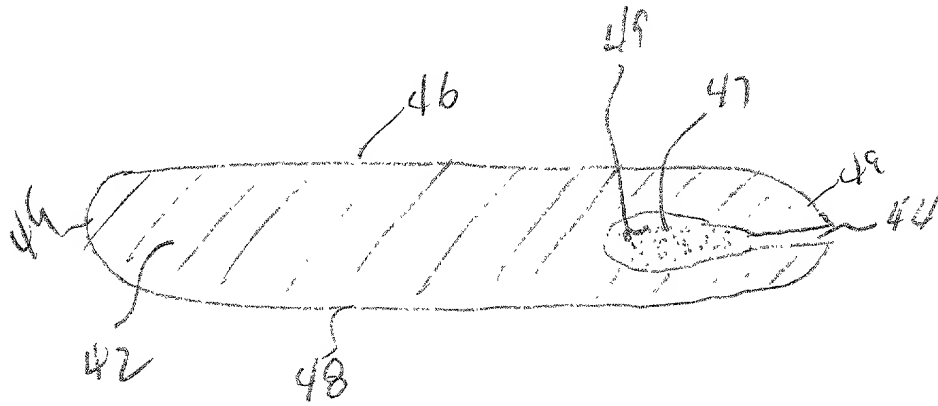


FIG. 10

DECLARATION FOR PATENT APPLICATION

Docket No. 6006-018

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **DEVICE FOR IN VIVO DELIVERY OF BIOACTIVE AGENTS AND METHOD OF MANUFACTURE THEREOF** the specification of which:

\*\* check one \*\*  
☒ [X] is attached hereto.  
☐ [ ] was filed on \_\_\_\_\_  
as Application Serial No. \_\_\_\_\_  
and was amended on \_\_\_\_\_  
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION SERIAL NO.	FILING DATE	STATUS
		PATENTED, PENDING, ABANDONED

POWER OF ATTORNEY

As a named inventor, I hereby appoint the following attorneys to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

David G. Rosenbaum Reg. No. 31,872

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of first inventor: Christopher T. Boyle

Inventor's signature \_\_\_\_\_ Date \_\_\_\_\_

Residence: 5100 USSA Boulevard, #1624, San Antonio, Texas 78240

Citizenship: U.S.A.

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